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ABSTRACT

The purpose of this study was to determine the influence that varying types of labels have on the organization of a series of movements in memory. Subjects were presented with a series of movements on a positioning task. They were provided with numeric labels for each movement held in the series. Results indicated that labels play an important role in the storage and retrieval of serial movement information with temporal labels facilitating temporal organizational patterns and spatial labels promoting spatial organization. The influence appeared to remain strong even when the series length exceeded the capacity of short term memory. (JD)

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SPATIAL-TEMPORAL ORGANIZATION IN MEMORY OF A SERIAL MOTOR TASK

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INTRODUCTION

EMPLOYING SERIAL MOTOR TASKS TO STUDY THE ORGANIZATIONAL CHARACTERISTICS OF MOVEMENTS IN SHORT TERM MEMORY HAS BECOME POPULAR IN MOTOR LEARNING RESEARCH. IN GENERAL THIS RESEARCH HAS BEEN CHARACTERIZED BY PRESENTING SUBJECTS WITH A SERIES OF MOVEMENTS ON A POSITIONING TASK. THIS WOULD SUBSEQUENTLY BE FOLLOWED BY THE SUBJECTS REPRODUCING THE SERIAL ITEMS IN THE SAME ORDER THEY WERE PRESENTED. THIS SERIAL RECALL PARADIGM WAS EFFECTIVE FOR STUDYING RETENTION, HOWEVER, IT WAS LIMITED IN PROVIDING INFORMATION ABOUT THE ORGANIZATIONAL PROCESSES OCCURRING WITHIN THE PERFORMER.

WHEN DEALING WITH THE QUESTION OF HOW PEOPLE ORGANIZE INFORMATION, A BASIC PREMISE IS THAT THEY ARE ALLOWED TO ORGANIZE. SUCH A PREMISE FORCES A SHIFT IN METHODOLOGY AWAY FROM THE SERIAL RECALL PARADIGM. IN THE MID 1960's, TULVING (1962, 1964, 1965) INTRODUCED AND DEVELOPED THE FREE RECALL PARADIGM. THIS EXPERIMENTAL PROCEDURE ALLOWS THE SUBJECT TO REPRODUCE SERIALLY PRESENTED ITEMS IN ANY ORDER THE SUBJECT WISHES. BY OBSERVING THE PATTERNS OF RECALL THE MANNER OF ORGANIZATION MAY BE INFERRED.

FEW STUDIES IN THE MOTOR AREA HAVE EMPLOYED THE FREE RECALL TECHNIQUE. ONE OF THESE FEW STUDIES WAS CONDUCTED BY DIEWART AND STELMACH (1978). SUBJECTS IN THIS

STUDY REPRODUCED A SERIES OF FIVE MOVEMENTS IN ANY ORDER THEY WISHED. ALTHOUGH THESE MOVEMENTS WERE PRESENTED IN VARYING ORDERS, THE SUBJECTS HAD A VERY STRONG TENDENCY TO RECALL THE MOVEMENTS IN A SPATIALLY SEQUENTIAL ORDER, THAT IS THE SHORTEST MOVEMENT FIRST, FOLLOWED BY THE NEXT LONGEST, AND SO ON. THESE FINDINGS REVEALED THAT WHEN PERMITTED SUBJECTS COULD REORGANIZE MOVEMENT INFORMATION INTO A MORE MEANINGFUL FORM.

A SECOND ORGANIZATIONAL STRATEGY WAS REPORTED IN A STUDY CONDUCTED BY MAGILL AND HUSAK (1978). SUBJECTS IN THIS STUDY WERE PRESENTED WITH A SERIES OF 6, 9 or 12 MOVEMENTS ON A POSITIONING TASK. DURING REPRODUCTION SUBJECTS TENDED TO RECALL THE MOVEMENTS IN THE SAME ORDER THEY WERE PRESENTED. A CONFOUNDING VARIABLE IN THIS STUDY MAY HAVE BEEN THAT THE SUBJECTS WERE PROVIDED WITH NUMERIC LABELS FOR EACH MOVEMENT. THESE LABELS COINCIDED WITH THE POSITION THAT MOVEMENT HELD IN THE SERIES. THEREFORE, THE FIRST MOVEMENT PRESENTED HAD A LABEL OF "1", THE SECOND MOVEMENT "2", AND SO ON. THIS FORM OF LABELING MAY HAVE FACILITATED A TEMPORAL ORGANIZATIONAL PATTERN AND INHIBITED OTHER FORMS OF ORGANIZATION FROM OCCURRING. THE PURPOSE OF THIS STUDY, THEREFORE, WAS TO DETERMINE THE INFLUENCE THAT VARYING TYPES OF LABELS HAVE ON THE ORGANIZATION OF A SERIES OF MOVEMENTS IN MEMORY.

METHOD

IN ORDER TO INVESTIGATE THIS PROBLEM A SERIES OF THREE EXPERIMENTS WERE PLANNED. THE THREE EXPERIMENTS WERE ESSENTIALLY SIMILAR WITH THE ONLY DIFFERENCE BEING AN INCREASE IN THE LENGTH OF THE SERIES. EXPERIMENT "1" PRESENTED SUBJECTS WITH A SERIES OF 6 MOVEMENTS WHILE EXPERIMENTS "2" AND "3" PROVIDED SUBJECTS WITH A SERIES OF 9 AND 12 MOVEMENTS RESPECTIVELY. FORTY-FIVE MALE AND FEMALE UNDERGRADUATE VOLUNTEERS SERVED AS SUBJECTS IN EACH EXPERIMENT. A UNI-DIMENSIONAL POSITIONING APPARATUS (SHEA AND HUSAK, 1979) WHICH PERMITTED MOVEMENTS ALONG A TRACKWAY 76.2 CENTIMETERS IN LENGTH WAS EMPLOYED IN THE STUDY.

IN EXPERIMENT "1" THREE GROUPS WERE DEFINED ACCORDING TO THE MEANINGFULNESS OF THE NUMERIC LABEL ATTACHED TO EACH INDIVIDUAL MOVEMENT WITHIN A SERIES. IN THE RANDOM GROUP THE NUMBERS WERE ASSIGNED RANDOMLY TO EACH MOVEMENT IN THE SERIES. THE RANDOM LABELS DID NOT HAVE ANY PARTICULAR SIGNIFICANCE OTHER THAN TO IDENTIFY THE END LOCATIONS SO THAT IN THE RECALL STAGE THE SUBJECTS WOULD BE ABLE TO TELL THE EXPERIMENTER TO WHAT LOCATION THEY WERE MOVING. THE TEMPORAL GROUP RECEIVED LABELS THAT INDICATED THE TEMPORAL ORDER OF THE MOVEMENT PRESENTED. THEREFORE, THE FIRST POSITION PRESENTED WAS CALLED "1", THE SECOND POSITION "2", AND SO FORTH. THE THIRD GROUP WAS REFERRED TO AS THE SPATIAL GROUP. THE LABELS ATTACHED TO THE MOVEMENTS IN THIS GROUP PROVIDED SPATIAL INFORMATION ABOUT THE END POINT OF EACH POSITION IN

RELATION TO THE STARTING POINT. FOR THIS GROUP THE POSITION CLOSEST TO THE STARTING POINT WAS CALLED "1", AND THE MOVEMENT WITH END LOCATION FURTHEST AWAY WAS CALLED "6".

ALL SUBJECTS WERE PRESENTED WITH THREE SERIES OF MOVEMENTS. MOVEMENT EXTENTS WERE COUNTER-BALANCED ACROSS PRESENTATION POSITIONS TO CONTROL FOR DISTANCE BIASING. AFTER THE PRESENTATION OF A SERIES THE SUBJECT WAS ASKED TO REPRODUCE THE INDIVIDUAL MOVEMENTS IN THE SERIES IN ANY ORDER THEY WISHED AND PROVIDE THE MOVEMENTS NUMERIC LABEL. DURING THE REPRODUCTION PHASE, THE EXPERIMENTER RECORDED THE ORDER OF RECALL. THE PROCEDURES WERE IDENTICAL FOR EXPERIMENTS 2 and 3 WITH THE EXCEPTION OF AN INCREASE IN THE MOVEMENT SERIES FROM 6 to 9 and 12 MOVEMENTS, RESPECTIVELY.

R E S U L T S

OF INTEREST IN THESE SERIES OF EXPERIMENTS WAS THE DEGREE TO WHICH THE INDIVIDUAL MOVEMENTS WERE ORGANIZED EITHER TEMPORALLY OR SPATIALLY IN MEMORY. A TEMPORAL ORGANIZATIONAL PATTERN WOULD BE REFLECTED BY RECALL ORDERS SIMILAR TO THE ORDER OF PRESENTATION WHILE SPATIAL ORGANIZATION WOULD APPEAR IN RECALL PATTERNS ASSOCIATED WITH THE MOVEMENT DISTANCES OR END LOCATIONS.

A PRESENTATION ORDER BY RECALL ORDER BY GROUPS (6 x 6 x 3) CONTINGENCY TABLE WAS FORMED, AND THE OVERALL CHI-SQUARE REVEALED THAT THERE WAS A SIGNIFICANT TEMPORAL INFLUENCE (x^2=863.0, $p<.05$) ON THE ORGANIZATION OF THE MOVEMENT SERIES IN MEMORY.

PRESENTATION ORDER BY RECALL ORDER (6 x 6) CHI-SQUARES WERE THEN PERFORMED FOR THE RANDOM, TEMPORAL AND SPATIAL GROUPS AND EACH PROVED TO BE SIGNIFICANT (x^2=70.4, 643.2 and 149.4 respectively, $p < .05$) WITH THE MOST DIVERGING GROUP BEING THE TEMPORAL LABEL GROUP. PATTERNS OF RECALL THAT WERE THE MOST PROMINENT WERE THE STRONG TENDENCY TO RECALL EITHER THE FIRST OR LAST MOVEMENTS THAT WERE PRESENTED FIRST AND THE STRONG TENDENCY OF THE TEMPORAL GROUP TO RECALL THE MOVEMENTS IN THE SAME ORDER THEY WERE PRESENTED.

TO DETERMINE THE SPATIAL INFLUENCES ON ORGANIZATION A MOVEMENT DISTANCE BY RECALL ORDER BY GROUPS (6 x 6 x 3) CHI-SQUARE WAS PERFORMED. MOVEMENT DISTANCE PROVED TO BE A SIGNIFICANT FACTOR (x^2=703.5, $p < .05$) IN THE ORGANIZATIONAL PROCESS. SUBSEQUENT MOVEMENT DISTANCE BY RECALL ORDER (6 x 6) CHI-SQUARES REVEALED SIGNIFICANT SPATIAL INFLUENCES WERE FOUND IN THE RANDOM, TEMPORAL AND SPATIAL GROUPS (x^2=57.9, 167.6 and 578.0 respectively, $p < .05$) WITH THE SPATIAL GROUP BEING THE MOST DIVERGENT. AGAIN OBVIOUS PATTERNS OF RECALL APPEARED. FOR ALL THREE GROUPS THE INITIAL MOVEMENT RECALLED TENDED TO BE EITHER THE SHORTEST OR LONGEST MOVEMENT IN THE SERIES. THE SPATIAL LABEL GROUP, HOWEVER, WAS ABLE TO REORGANIZE THE STRUCTURE OF THE SERIES SO THAT A SEQUENTIAL OR SHORT TO LONG ORDER OF RECALL BECAME EVIDENT.

IN EXPERIMENT 2 THE LENGTH OF THE MOVEMENT SERIES WAS INCREASED FROM 6 to 9 MOVEMENTS. SIMILAR ANALYSES AS DESCRIBED FOR EXPERIMENT "1" WERE CONDUCTED. AGAIN THE OVERALL TEMPORAL INFLUENCE PROVED TO BE SIGNIFICANT (x^2=1,939.9, $p<.05$) AND WAS ALSO SHOWN TO BE SIGNIFICANT FOR ALL THREE GROUPS (x^2=136.2, 1,420.1 and 383.6 FOR THE RANDOM, TEMPORAL AND SPATIAL GROUPS RESPECTIVELY, $p<.05$) WITH THE GREATEST DIVERGENCE BEING OBSERVED IN THE TEMPORAL GROUP. THERE WAS A STRONG TENDENCY FOR THE RANDOM GROUP TO RECALL FIRST OR LAST THE MOVEMENTS THAT WERE PRESENTED FIRST OR LAST IN THE SERIES. ALSO THE TEMPORAL GROUP RETAINED ITS STRONG TENDENCY TO RECALL THE INDIVIDUAL ITEMS IN THE ORDER THAT THEY WERE PRESENTED.

SPATIAL INFLUENCES ON THE ORDER OF RECALL WERE FOUND FOR THE TEMPORAL AND SPATIAL GROUPS BUT NOT FOR THE RANDOM GROUP (x^2=344.2, 1,235.0 and 68.4 RESPECTIVELY, $p<.05$). THE MOST NOTICEABLE PATTERN OF RECALL FOR THE TEMPORAL GROUP WAS THE TENDENCY TO RECALL THE SHORTEST OR LONGEST MOVEMENT FIRST. AS IN EXPERIMENT "1" THERE WAS A STRONG TENDENCY FOR THE SPATIAL GROUP TO AGAIN RECALL THE ITEMS IN A SHORT TO LONG MANNER.

IN ORDER TO EXCEED THE CAPACITY OF SHORT-TERM MEMORY THE LENGTH OF THE SERIES WAS INCREASED FROM 9 to 12 MOVEMENTS IN EXPERIMENT 3. THE OVERALL CHI-SQUARES PROVED TO BE SIGNIFICANT FOR BOTH TEMPORAL (x^2=2,271.2, $p<.05$) AND SPATIAL

(x^2=2,180.6, $p<.05$) INFLUENCES. IN THE FOLLOW-UP ANALYSIS IT WAS REVEALED THAT ALL THREE GROUPS DEMONSTRATED SIGNIFICANT TEMPORAL INFLUENCES (x^2=223.6, 1,550.1 and 497.5 for the random, temporal and spatial groups respectively, $p<.05$). THE RANDOM GROUP TENDED TO RECALL THE LAST POSITION FIRST. ONCE AGAIN THE TEMPORAL GROUP TENDED TO RECALL THE MOVEMENTS IN THE SAME ORDER THEY WERE PRESENTED. HOWEVER, THERE DOES BEGIN TO APPEAR A PATTERN OF REVERSE RECALL IN WHICH THE LAST POSITION PRESENTED WAS RECALLED FIRST, THE SECOND TO LAST POSITION PRESENTED BEING RECALLED SECONDLY, AND SO ON. EACH GROUP WAS ALSO SIGNIFICANTLY INFLUENCED BY THE SPATIAL FACTORS (x^2=239.9, 503.5 and 1,437 for the random, temporal and spatial groups respectively, p .05). AS WAS EXPECTED THE SPATIAL GROUP HAD A VERY STRONG TENDENCY TO RECALL THE POSITIONS IN A LONG TO SHORT FASHION. THE RANDOM GROUP ALSO HAD A PROPENSITY TO RECALL EITHER THE SHORTEST OR LONGEST POSITION PRESENTED IN THE SERIES FIRST.

DISCUSSION

THE RESULTS OF THE PRESENT SERIES OF EXPERIMENTS CLEARLY INDICATE THE POWERFUL ROLE THAT LABELS PLAY IN THE STORAGE AND RETRIEVAL OF SERIAL MOVEMENT INFORMATION. TEMPORAL LABELS FACILITATE TEMPORAL ORGANIZATIONAL PATTERNS WHILE SPATIAL LABELS PROMOTE SPATIAL ORGANIZATION. FURTHERMORE, THIS INFLUENCE APPEARS TO REMAIN STRONG

EVEN WHEN THE SERIES LENGTH EXCEEDS THE CAPACITY OF SHORT TERM MEMORY. ALSO DEMONSTRATED WAS THE FACT THAT ALTHOUGH THESE LABELS DID PLAY A SIGNIFICANT ROLE IN HOW MOVEMENT INFORMATION WAS STORED, THEY DID NOT ELIMINATE THE INFLUENCE OF THE REMAINING CHARACTERISTIC IN THE ORGANIZATIONAL PROCESS. THIS MAY BE DUE TO THE FACT THAT MOVEMENT ORGANIZATION IS RARELY DEPENDENT UPON A SINGLE CHARACTERISTIC. IN FACT IT IS OFTEN AN INTERACTIVE COMBINATION OF BOTH THE TEMPORAL AND SPATIAL FEATURES OF THE MOVEMENT.

PRACTICAL APPLICATIONS OF THESE FINDINGS MAY INDICATE THE IMPORTANCE OF KEY PHRASES DURING INSTRUCTION AND PERFORMANCE WHICH WOULD FACILITATE THE ORGANIZATION OF MOVEMENT INFORMATION IN THE DESIRED DIRECTION.

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